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Forest and Range
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Research
Paper INT-299

December 1982

Measurements of Airtanker Drop Conditions During Firefighting Operations

Charles W. George

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ACKNOWLEDGMENTS

The author gratefully acknowledges financial, technical, and cooperative assistance by several individuals, agencies, and organizations in accomplishing the study described in this report. Among them are:

Hemet Valley Flying Service
- Jim Venable
- Richard Ruggiero
- Dud Westlake
- Russ Peters

California Department of Forestry
- Cotton Mason
- Ken Sigsbee
- Larry Benson

USDA Forest Service
- San Dimas Equipment Development Center
  - Herb Shields
- San Bernardino National Forest
  - Frank Vallesillo

Washington Office, A&FM, Boise Interagency Fire Center
- Dale Gable

RESEARCH SUMMARY

Various operational parameters were measured on actual retardant dropping missions using an instrumented S2F airtanker. The variables included drop height, drop configuration and tank release sequence, delay time, indicated airspeed, minimum height above fuel, and various use characteristics. The interpretation of real-time operational data was investigated and the importance of various factors determined. Results confirmed the validity of aircraft evaluation procedures and instrumentation. Drop heights measured during actual operations support guidelines and general assumptions made in previous studies.

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Approved for Publication by Intermountain Station March 1982

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INTRODUCTION

Aircraft drop height, speed, attitude, and other factors can drastically affect the distribution and effectiveness of retardant dropped from airtankers. Numerous studies have attempted to evaluate operationally the relative influence of factors such as type of retardant, aircraft, tank and gating system, and firefighting strategy. The studies have usually been inconclusive due to the large number of variables (many interacting), the magnitude of the effect of these variables, and the difficulty in quantifying the overall effectiveness of the retardant application (change in fire behavior, etc.). Guidelines derived from controlled tests are often not fully accepted, mainly because of lack of operational verification and disbelief in comparability of test conditions and field conditions.

The tank and gating system, volume of retardant dropped, drop configuration (number and position of compartments released), release sequence and interval, retardant type, wind, and aircraft height, speed and attitude may strongly affect retardant distribution. Many of these variables have been difficult to measure and have often been ignored in past studies.

Fire management economists, air attack specialists, chemical engineers, equipment design engineers, firefighters, and others are demanding more precise descriptions of drop conditions, tank and gating performance, and retardant distribution.

PREVIOUS RESEARCH

Many drop tests have been conducted to evaluate various aspects of retardant delivery and tank and gating system performance (Davis 1959; Johansen and Shimmel 1967; George and Blakely 1973; Grigel and others 1974). The drop conditions (drop height above ground and drop speed) were estimated from readings taken by the pilot or copilot, from measurements using a ground-based theodolite and timing devices, or determined from photographs of the drops. Although aircraft height and speed have often been estimated with good precision, relatively small changes (± 25 ft [7.6 m]) in drop height are known to alter drop patterns significantly (George 1975; Swanson and others 1978), especially at drop heights where total retardant breakup is incomplete (100 to 300 ft [30.5 to 91.4 m], depending on the tank and gating system and load size). Utilizing high-speed cameras equipped with electronic timing devices and analyzing the films using sophisticated motion analysis equipment, greater accuracy in measurements of drop conditions under controlled conditions has been achieved (George and Blakely 1973; George 1975).

Although drop conditions have been measured in various ways and with different degrees of accuracy, a continuing question has been whether the conditions (especially drop heights) used in specific drop studies are actually representative of conditions during operational use. Drop height estimates from firefighting personnel on the ground and air attack specialists have typically been lower than values determined photographically or by other means. Such estimates frequently have been lower than specified; for instance, the 150-ft (45.7-m) above-tree-canopy safety minimum established by the USDA Forest Service. Although observers have disagreed as to whether estimates were "above ground"—"above fuel or canopy"—determining drop height for analysis or study has been controversial.

The effect of aircraft speed on retardant distribution over the range of drop speeds normally encountered (120 to 160 knots [61.7 to 82.3 m/s]) has been found to be significantly less than the effect of drop height (George 1975; Swanson and others 1976, 1978). Increasing air-

craft velocity with respect to the ground has been shown to generally reduce peak pattern coverage values and increase low coverage lengths. On-board aircraft velocity-indicating devices, however, provide an airspeed that is often at variance with ground speed because of wind. In addition to affecting airspeed, the wind velocity profile and the orientation of the aircraft to existing winds can significantly affect the retardant delivery. Although wind affects the dispersion of retardant, its primary influence is to displace the retardant cloud and pattern, and thus affect accuracy.

The number of tanks released on each pass and the interval between gate openings has been a primary method of controlling the retardant distribution. The volume of retardant for a simultaneous tank release and the sequence or time interval between consecutive tank releases has often been used to create the desired retardant pattern for a fuel/fire situation or to cope with specific drop conditions (terrain, wind, or other factors). During retardant evaluations other than under highly structured or controlled studies, the drop configuration—especially the sequential drop delay times—has not always been readily available or measurable.

Other factors known to influence ground pattern distributions to a lesser but sometimes significant degree are the aircraft attitude or "g" force on the wing at release (dive, bank, or loft mode) and the topography. Although the importance of these factors has been difficult to measure, their effects have been sufficiently determined for the needs of retardant distribution studies by the previous research discussed and empirical observations.

STUDY DESCRIPTION

The purpose of the study was (1) to identify methods that can be used to more thoroughly determine the conditions under which fire retardants are dropped operationally, and (2) to collect data that would substantiate or better define the operational use envelope. The study was conducted at Hemet, Calif., in cooperation with the California Department of Forestry (CDF). About 2.5 million gallons (9.5 million liters) of fire retardant are delivered annually to fires on both State of California and National Forest land from the Hemet Air Attack Base. Study objectives were to instrument one of the CDF airtankers, an S2F, and collect specific data during drops, along with general information regarding the type of drop, the target, fuel, and surrounding terrain. The S2F (Tracker), originally built by Grumman Aircraft Co. as a carrier-based antisubmarine aircraft, was modified to carry 800 gallons (3 028 liters) of retardant in four compartments containing approximately 200 gallons each. The particular S2F selected for the study (Tanker 73, N406DF) contained an "Aero-Union" type tank whose characteristics and performance have been quantified in the Airtanker Performance Guides (Swanson and others 1976).

INSTRUMENTATION AND PROCEDURES

Drop height

A pulse radar altimeter system (Honeywell Model 7600) was selected to provide a continuous record of drop height. The system is composed of a receiver/transmitter, two antennas, and a height indicator. In addition to providing high resolution, the altimeter produces leading edge tracking for actual distance between the aircraft and the nearest terrain or obstacle with an accuracy of 3 ft (0.9 m) ± 2 percent. The receiver/transmitter, designed for integral use in military or commercial aircraft, provides an output that can be continuously recorded.

The radar altimeter antennas require mounting approximately 3 ft (0.9 m) apart on a level area of the aircraft skin, free from disruption and protuberances and from wheel interference. This was accomplished on the S2F by mounting the antennas on the bottom side of the right wing at a distance from the fuselage (fig. 1).

Figure 1.—Radar altimeter antennas mounted on the underside of the wing of a California Department of Forestry S2F airtanker.

Because drop height only during the actual drop was desired, an adjustable timer was provided to shut off the recording device after a preset time. An arming switch was mounted within easy reach of the pilot so that prior to a drop, the recorder could be started. This provided a continuous trace of drop height until the recorder was automatically shut off. This procedure minimized the additional amount of attention needed by the pilot to operate the system.

A high-speed, fast-response strip chart recorder (Gould Brush Model 260) was used to record the drop height. The recorder had six channels and contained built-in event markers to provide a method of recording additional parameters and events (discussed later). A simplified schematic of the on-board instrumentation, including the radar altimeter/drop height-measuring system, is shown in figure 2.

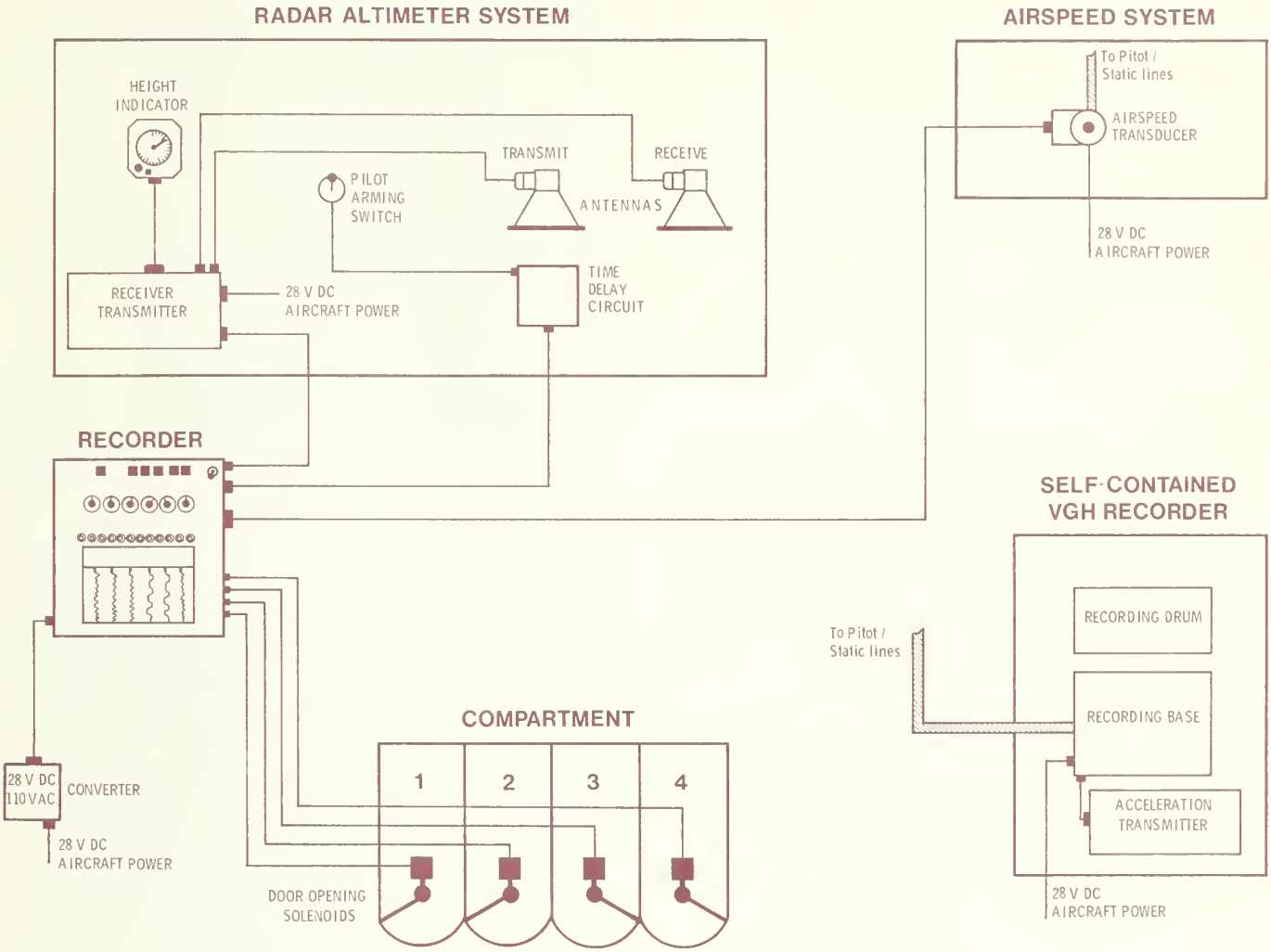

Figure 2.—Schematic of onboard instrumentation.

Drop Configuration and Release Sequence

The release of retardant was correlated to the drop height recording by utilizing the electrical circuit from the door-opening system. The signals at the door-opening solenoids for the four doors were recorded on the six-channel strip chart recorder. The release switch, activated by the pilot, was not used because a slight delay was found between the switch activation and activation of the solenoid and door opening. Recording signals from the door solenoids allowed the monitoring of door-opening when the automatic intervalometer system for sequential or trail drop releases was used, and provided the delay time between releases.

Indicated Airspeed

A pressure transducer was used to measure the aircraft indicated airspeed at the time of the drop (airspeed transducer Bourns Model 538 and Celesco Model CP51DT). The pressure transducer, designed to provide indicated airspeed inputs to an auto pilot, air data computer, or other flight control or monitor system, produces an electrical signal linear with airspeed. Indicated airspeed was monitored by connecting the pressure transducer to the aircraft pitot-static lines.

General Operational Information

A basic VFGH recorder was used to obtain time-history records of aircraft speed, altitude, and normal acceleration during an entire operational mission. From this history, information such as flight duration, time to first drop, dash speed to first drop, rate of descent, maneuver acceleration fraction, drops per flight, time between drops, maximum airspeed, and time from last drop to touchdown can be determined. This information was used to help define the overall mission envelope, as well as interpret recorded data.

The recorder was a basic NASA (National Aeronautics and Space Administration) VGH recorder (Model 47) that contains two pressure-sensitive elements for measuring airspeed and altitude, a galvanometer element for measuring the output of an acceleration transmitter, and a timing mechanism. Data are recorded on photographic paper supplied on removable recording drums. The VGH recorder, being a self-contained system, operated independ-

ently from the other on-board measuring systems that have previously been discussed.

A flight log and fire record were kept on each fire mission for which on-board recordings were taken. The information was requested from the airtanker pilot, AIRCO (Air Attack Coordinating Officer), and/or lead plane pilot, and, in addition to normal records (date, time, fire, response area, etc.), provided a description of the fuel characteristics (type, canopy height, etc.), estimated drop height and speed, drop configuration, retardant type, and sketch of the fire perimeter, terrain features, etc., showing approach, tactics, etc. When time and circumstances allowed, the information (especially fuel canopy height) was verified by personnel on the ground.

RESULTS

The study was initiated with the calibration (static test and in-flight) of on-board instrumentation and a thorough review of the program with the air attack personnel involved in the study. During the 1979 fire season, on-board data were collected during 52 operational fire missions. Although minor problems occurred, the primary data-gathering system worked well.

Release Configurations

Data for all drops were tabulated and summarized in appendix table 2. The records of drop conditions provided by the airtanker pilot and air attack personnel were compared with recorded data, and any omissions or differences reconciled. A breakdown of the 52 missions flown, by type of drop or release configuration, is given in the following tabulation.

Release configuration	Missions Number	Missions Percent
Salvo - 4-door 4 compartments, 800 gal (3 028 liters)	2	4
Salvo - 2-door 2 compartments, 400 gal (1 514 liters)	2	4
Trail drop 1 × 2,[1] 400 gal (1 514 liters)	3	6
Trail drop 1 × 4, 800 gal (3 028 liters)	21	40
Trail drop 2 × 2, 800 gal (3 028 liters)	24	46

[1]A trail drop noted as 1 × 2 refers to the number of compartments released times the number of releases.

The data indicate very few four-compartment, 800-gallon (3 028-liter) salvo drops were made with the S2F. Although use in an area of considerably heavier fuel might increase the percentage of 800-gallon salvos, it appears that a much greater number of releases of lesser volumes, mainly in the trail or sequential release mode, are the general practice. This is probably significant in view of the general feeling that a majority of the drops made with the S2F are salvos, due to its relatively small total capacity. One possible reason for the low percentage of salvo drops may have been the large accelerations experienced from pitch-up when the released retardant blanks the upload on the S2F's horizontal stabilizer and, hence, a recommendation against high-speed salvo drops (Watts and others 1978). Use of a very short delay time and sequential or trail drop to circumvent pitch-up would be shown by recorded time-delay data.

When the performance of the S2F is considered, using the airtanker performance guides together with the fuels in which the majority of the missions were flown, the types of releases being made are as would be expected. From a tactical standpoint, however, it is surprising that the load is split (more than one pass and release) on only 10 percent of the missions, since multiple drops are often used to pinch off or "x" the front of a spreading fire. Perhaps more than one airtanker is being used to obtain this result, or ground attack personnel are used to the extent that this tactic is only infrequently used.

Analysis of recorded delay times for trail or sequential drops indicated no significant difference between door-opening delays for different drop configurations (1 × 4, 1 × 2, 2 × 2). Furthermore, delay times revealed no trends in either drop speed or drop height. In a few specific instances, however, a very fast trail may have been used to accomplish a slightly delayed 800-gallon salvo (reduced flow rate).

The distribution of delay intervals for all sequential or trail releases (fig. 3) indicates that a delay time between releases of 0.3 and 0.5 seconds was used for 71 percent of all drops. The average delay for all drops was 0.395 seconds, and the median was 0.402 seconds. Delay times were definitely reduced when more than one sequential drop was made, the average delay for the first, second, and third delay being 0.401, 0.394, and 0.384, respectively. Inspection and analysis of the door-opening histories, in addition to the increasing door-opening speed, also indicate the door-opening intervalometer was seldom, if at all, used. The pilot favored manual activation of the release button (confirmed by the pilot). Although the delays in trail releases were fairly consistent, they were not repetitive. It is possible that manual release was utilized so delay time could be adjusted to compensate for aircraft speed, topography, fuel, fire conditions, or other factors. Flight tests have also demonstrated that delay time is critical for minimizing aircraft pitch-up after release. Use of the manual release rather than the automatic intervalometer system also results from lack of definite settings on the switch (a variable-speed potentiometer is used providing continuous "slow" to "fast" settings), possibly leading to a lack of pilot confidence in the system. (Nearly all CDF S2F's have identical intervalometer systems.)

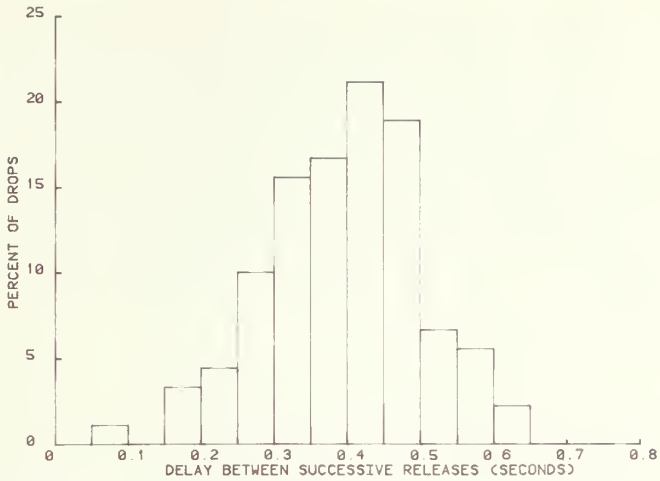

Figure 3.—Delay times for sequential or trail drops.

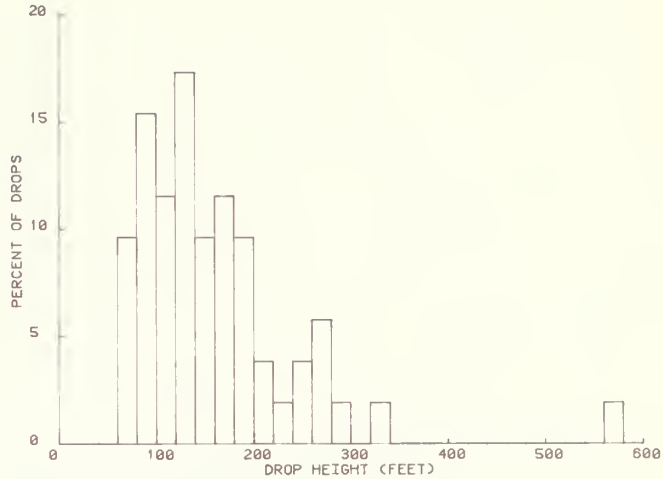

Figure 4.—Drop height above the fuel at initial door opening.

Drop Height

The drop height (above the fuel or canopy), determined from recordings from the pulse radar altimeter system for each drop, was analyzed. The height at initiation of door opening for each compartment was determined. (The initiation of door opening for each door was recorded on the same time-base strip chart as the drop height.) Thus, for a single-door trail drop (1 × 4), the height at the time of each of the four door openings was determined. The minimum drop height occurring during the pass, as well as the time it happened in relation to the initial release, was also noted. Specifics for each drop can be found in table 2 (see appendix).

The distribution of drops by drop height above the fuel at the time the first door is opened is shown in figure 4. The lowest height at the initiation of release was 63 ft, and the highest 564 ft. The average height for all releases at drop initiation was 160 ft; the median was 144 ft. Because visual examination of the traces indicated that the drop height tended to decrease following the initial release, with the absolute minimum usually occurring after the last release, a similar analysis of drop heights at successive releases made during the same pass (sequential or trail drop) was conducted. The analysis showed the average heights at the point of the second, third, and fourth release were 150, 118, and 109 ft, respectively; the corresponding median heights were 127, 114, and 112 ft. The median for consecutive releases following the initial release was determined from a smaller sample, however, with 40 percent of the drops being 1 × 4 and 50 percent being 2 × 2 trail drops. A definite trend of decreasing drop height following release can be concluded. (All average and median drop heights are shown in table 1.) Assuming that uphill drops (considered a poor practice or prohibited for safety reasons) were not being made, the lowest drop height for a pass usually occurs significantly after initial release. To further define the minimum absolute drop height, its occurrence in relation to the initial release was determined from the strip-charts and recorded. Using these observations, the frequency of minimum heights for all missions or passes and the time of occurrence with reference to the initial release was determined and is shown in figures 5 and 6.

Table 1.—Comparison of average and median drop heights for all releases

Drop sequence	Number in sample	Drop height	
		Average	Median
		----- *Feet* -----	
1 (initial)	52	160	144
2	52	150	127
3	21	118	114
4	21	109	112
	n = 146	$\overline{DH}$ = 143	DH_m = 123

Although the point of release provides a definite point from which height can be measured, it does not always coincide with the height or trajectory of the retardant. (The drop height and the initial height are similar when the flight path and ground are relatively level, or when the flight parallels the slope of the land.) Thus, drop height (especially minimum drop height) must be monitored from initial release until the retardant is evacuated from the tank.

Flow rate tests of the "Aero-Union-tanked" type S2F (similar to the tanker used in this study) previously conducted had door-opening times of 0.26 to 0.32 seconds for any door-opening combination, and retardant evacuation

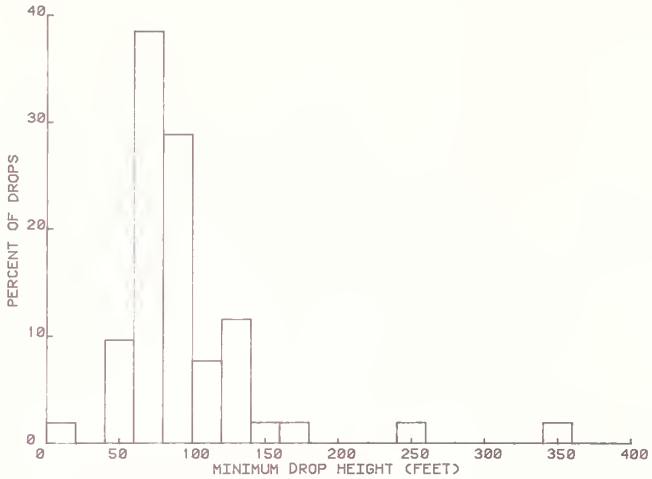

Figure 5.—Minimum drop heights.

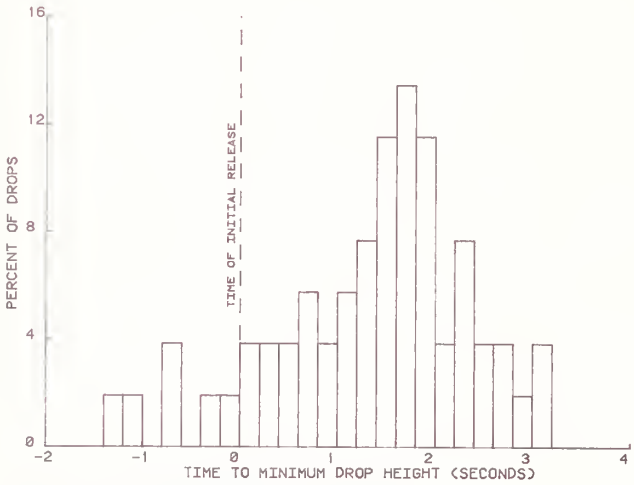

Figure 6.—Variation in time from initial release to minimum height.

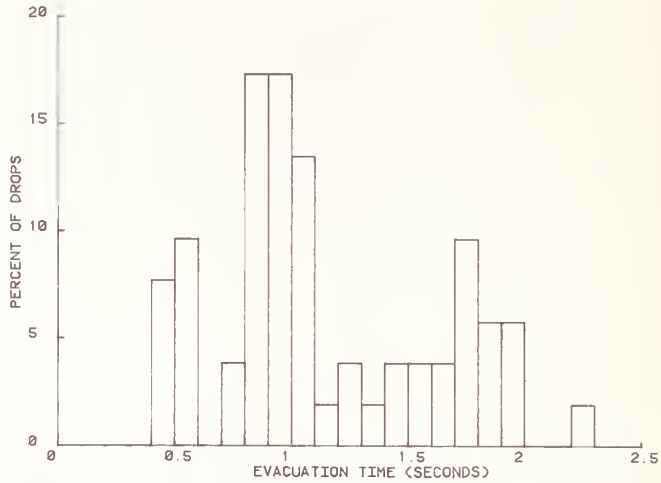

Figure 7.—Evacuation time for all drops.

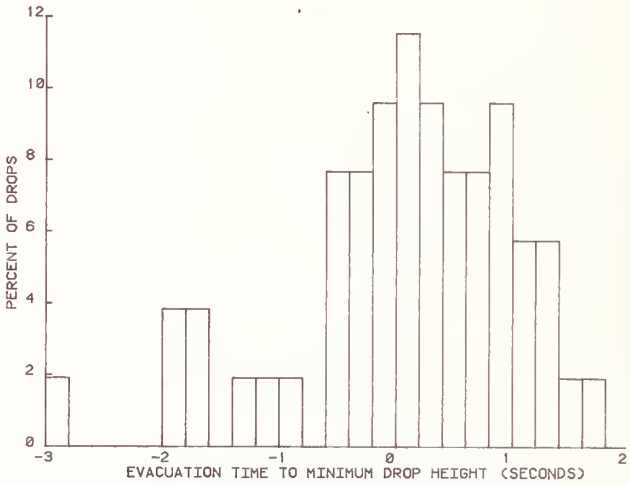

Figure 8.—Variation in time from tank evacuation to minimum height.

times of 0.50 seconds (Swanson and others 1976). The door-opening times were found to be faster than the acceleration of the fluid and multiple door opening did not alter the door-opening rates. Thus, evacuation time was constant for all drops. Hence, the 0.50-second constant evacuation time added to any delays occurring for other than salvo drops defined the period of interest for which drop height changes may have occurred. Figures 7 and 8 show the frequency of time required for all retardant to be evacuated from the tank or tanks and the time from evacuation (time 0) to the minimum drop height. (Negative values indicate the minimum drop height occurred prior to the evacuation of the retardant.) Because the minimum drop height occurred before the tanks were evacuated in 40 percent of the drops and after evacuation in 60 percent of the drops, and because the large majority of the drops were in a trail or sequential configuration, it appears the drop height at the point of initial release would be most representative of the drop height influencing retardant breakup and dispersion. Drop height during the time from or before initial release to evacuation can be measured using recordings from the radar altimeter; however, a visual examination of the recording is normally sufficient to determine whether significant changes in drop height have occurred during actual retardant release.

The average minimum height for all missions was 94 ft (28.7 m), and the median 86 ft (26.2 m). The minimum height was less than the height at the time of initial release during 98 percent of the missions (160 ft [48.9 m] average height at release compared to 94 ft [28.7 m] average minimum drop height).

Indicated Airspeed/VGH Recordings

Due to problems in obtaining, installing, calibrating, and maintaining the airspeed monitoring instrumentation (including VGH recorder), no VGH airspeed data were obtained during the 52 missions. By monitoring the airspeed transducer, however, the indicated airspeeds during 13 missions and during 34 releases were obtained. Although limited data were obtained with the instrumentation, the methods of data collection and the data proved to be adequate.

The average indicated airspeed for those drops monitored was 119 knots (61.2 m/s); the median was 124 knots (63.8 m/s). The frequency of indicated airspeed for all drops is shown in figure 9, drops ranging from 97 to 135 knots (49.9–69.4 m/s). The drop speed at door opening

for trail or sequential drops tended to increase for consecutive releases. The average airspeed being 116, 118, 122, and 125 knots (59.7, 60.7, 62.8, and 64.3 m/s) for the four releases of a 1 × 4 sequence (the medians for the four releases showed corresponding airspeeds of 121, 125, 127, and 129 knots [62.2, 64.3, 65.3, and 66.4 m/s], respectively), this trend would normally be expected because most drops are made downhill (decreasing drop heights during the drop were confirmed), and under such conditions, airspeed is less controllable.

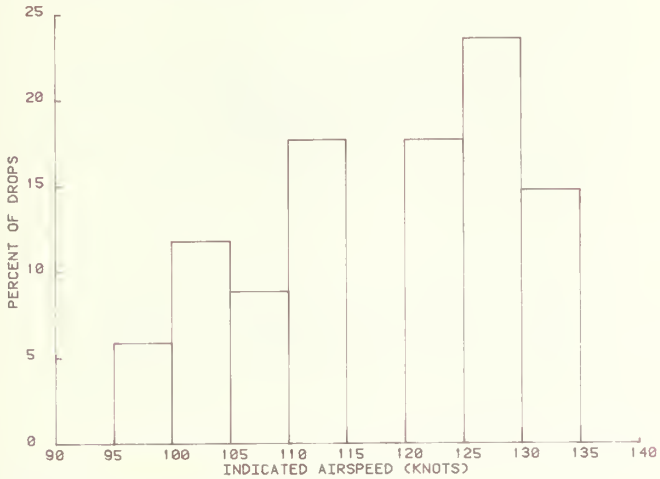

Figure 9.—Indicated airspeeds at time of release.

Although VGH recordings were not obtained for the 52 missions monitored, the operation and usefulness of such data have been previously demonstrated. General operational and flight envelope information has been obtained by J. Jewel, NASA, using recorders on DC6, DC7, C119, and S2F airtankers during 1972–74 fire seasons.[1] Data collected during approximately 513 flight hours and for 1 658 drops (722 missions) for the four aircraft were reported. Data included flight duration histories, times to drop, drop speeds, and rates of descent. Examples of such data collected for a CDF-Hemet Valley Flying Service S2F during September to November 1974 are shown in figure 10. These data, although collected for the same type of aircraft and for missions flying from the same air attack base, may only be generally related to the data and findings resulting from this study. The histories (times) for particular missions are likely similar; however, drop configurations were different. Salvo drops predominated during the 1974 study; in this study, the majority were trail or sequential drops.

VGH recordings can provide information that can be useful when defining drop conditions and flight envelopes and when interpreting and verifying associated in-flight monitoring systems.

[1]Jewel, J. NASA, Report to the National Airtanker Screening and Evaluation Board. March 12 and 13, 1975, Reno, NV.

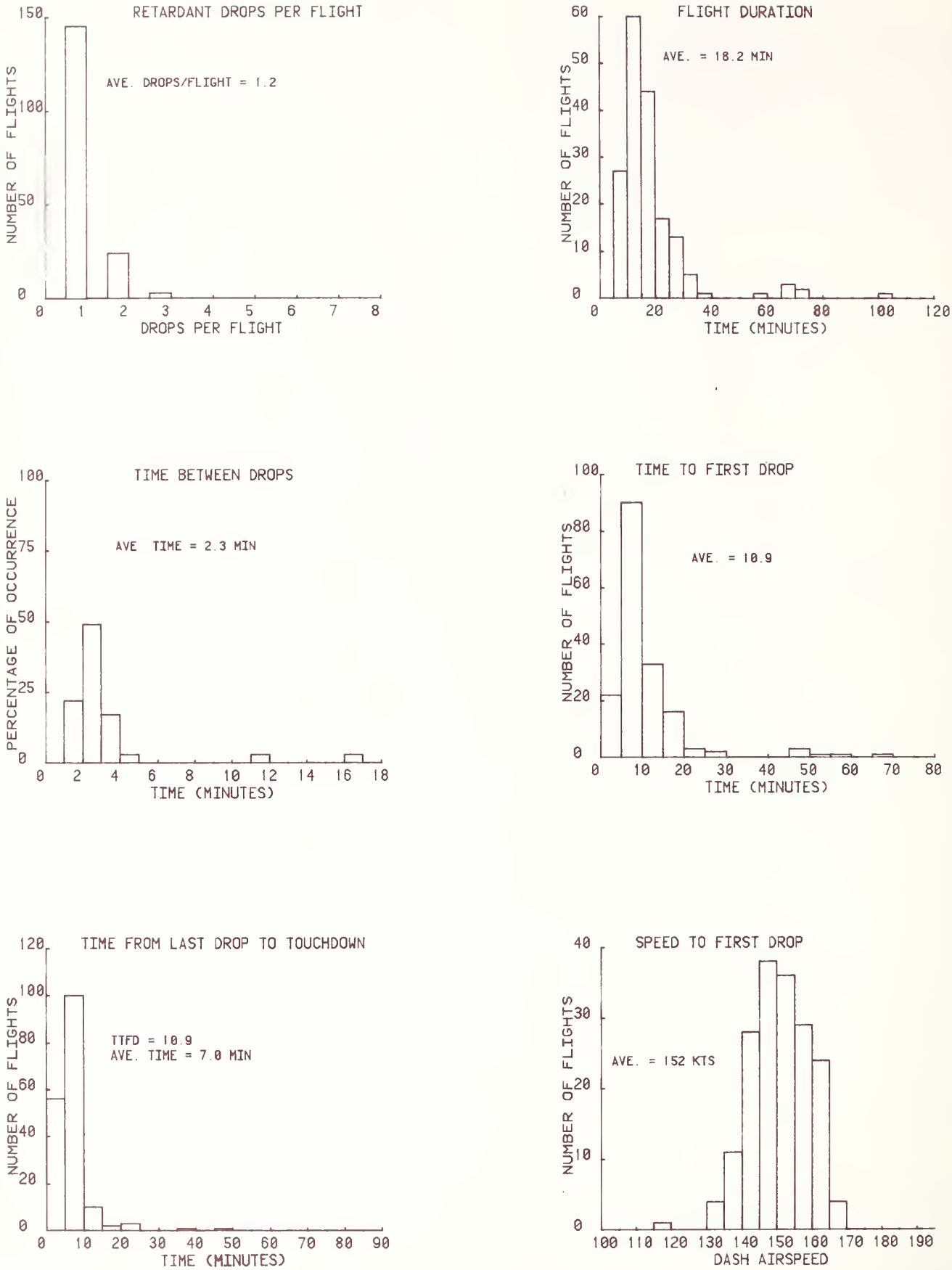

Figure 10.—Examples of data summarized from VGH recordings in a CDF-Hemet Valley Flying Service S2F airtanker (from J. Jewel, NASA, 1975).

CONCLUSIONS

Data concerning operational aerial retardant use were gathered on actual retardant-dropping missions and analyzed. The data and subsequent analysis confirm that the procedures for evaluating airtanker performance and retardant distribution including instrumentation on simulated drops are sound and adequate.

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Table 2.—Summary of on-board data collected during the study

DATE	FIRE ID NAME	FIRE ID No.[1]	DROP TYPE	DROP HEIGHT (FT)[2] 1	2	3	4	AIRSPEED (KNOTS)[2] 1	2	3	4	DELAY (SEC)[3] 1	2	3	MIN HEIGHT (FT)	TIME TO MIN HEIGHT (SEC)[4]	EMPTY TIME
8/09/79	FLATS 1	1195	2X2	90	74	0	0	0	0	0	0	0.49	0.00	0.00	64	1.14	0.99
8/09/79	FLATS 2	1195	1X4	123	119	119	124	0	0	0	0	0.35	0.34	0.30	60	1.76	1.49
8/09/79	FLATS 3	1195	2X2	74	73	0	0	0	0	0	0	0.33	0.00	0.00	63	1.10	0.83
8/09/79	FLATS 4	1195	2X2	99	65	0	0	0	0	0	0	0.39	0.00	0.00	65	0.36	0.89
8/09/79	FLATS 5	1195	1X4	150	149	128	111	0	0	0	0	0.35	0.36	0.31	73	2.24	1.52
8/09/79	FLATS 6	1195	1X4	126	119	113	100	0	0	0	0	0.39	0.39	0.42	68	2.52	1.70
8/10/79	EDEN	1206	2X2	153	155	0	0	0	0	0	0	0.38	0.00	0.00	78	1.28	0.88
8/17/79	RC ASSIST	12-759	1X2	261	181	0	0	0	0	0	0	0.60	0.00	0.00	98	2.02	1.10
8/18/79	JOSHUA 1	1252	1X4	111	99	88	84	0	0	0	0	0.48	0.50	0.46	86	1.44	1.94
8/18/79	JOSHUA 2	1252	1X4	174	171	144	125	0	0	0	0	0.34	0.47	0.40	95	2.74	1.70
8/18/79	JOSHUA 3	1252	1X4	76	85	110	123	0	0	0	0	0.50	0.49	0.47	74	0.15	1.96
8/18/79	RAWSON 1	1256	1X2	63	81	0	0	0	0	0	0	0.52	0.00	0.00	63	0.00	1.02
8/18/79	RAWSON 2	1256	1X2	174	160	0	0	0	0	0	0	0.41	0.00	0.00	65	2.27	0.91
8/18/79	RAWSON 3	1256	2X2	111	146	0	0	0	0	0	0	0.55	0.00	0.00	99	-0.33	1.05
8/18/79	RAWSON 4	1256	1X4	99	86	73	61	0	0	0	0	0.26	0.28	0.28	41	1.50	1.31
8/18/79	RAWSON 5	1256	1X4	175	161	138	113	0	0	0	0	0.48	0.40	0.37	78	2.04	1.75
8/18/79	RAWSON 6	1256	1X4	98	101	103	108	0	0	0	0	0.25	0.26	0.26	76	-0.69	1.28
8/18/79	RAWSON 7	1256	1X4	186	175	174	143	0	0	0	0	0.48	0.41	0.42	85	2.92	1.80
8/18/79	RAWSON 8	1256	1X4	169	164	149	136	0	0	0	0	0.45	0.43	0.36	135	1.52	1.74
8/19/79	JOSHUA 4	1252	1X4	101	103	95	88	0	0	0	0	0.35	0.38	0.36	89	1.68	1.59
8/24/79	BURRO	12-986	2X2	328	365	0	0	0	0	0	0	0.34	0.00	0.00	136	2.60	0.84
8/25/79	HALL 1	1297	2X2	159	106	0	0	0	0	0	0	0.55	0.00	0.00	98	0.95	1.05
8/25/79	HALL 2	1297	2X2	151	124	0	0	0	0	0	0	0.44	0.00	0.00	61	1.36	0.94
8/25/79	HALL 3	1297	2X2	88	76	0	0	0	0	0	0	0.43	0.00	0.00	51	1.14	0.93
8/27/79	CREEK	1310	2X2	89	111	0	0	0	0	0	0	0.38	0.00	0.00	75	-0.76	0.88
8/29/79	CABAZON 1	12-1086	2X2	298	285	0	0	0	0	0	0	0.10	0.00	0.00	138	0.56	0.60
8/29/79	CABAZON 2	12-1086	2X2	125	126	0	0	0	0	0	0	0.33	0.00	0.00	124	0.70	0.83
8/29/79	CABAZON 3	12-1086	2X2	268	248	0	0	131	131	0	0	0.48	0.00	0.00	133	1.90	0.98
8/29/79	CABAZON 4	12-1086	2X1	184	0	0	0	102	0	0	0	0.00	0.00	0.00	135	1.76	0.50
8/29/79	CABAZON 5	12-1086	2X2	564	513	0	0	0	0	0	0	0.28	0.00	0.00	356	3.15	0.78
8/29/79	CABAZON 6	12-1086	1X4	239	215	200	176	110	105	105	110	0.28	0.24	0.24	90	1.72	1.26
8/29/79	CABAZON 7	12-1086	2X2	256	274	0	0	99	97	0	0	0.32	0.00	0.00	249	-0.17	0.82
8/30/79	WASSON 1	1337	1X4	120	124	115	111	113	113	114	121	0.33	0.36	0.29	100	1.24	1.48
8/30/79	WASSON 2	1337	1X4	138	128	118	123	125	124	128	127	0.34	0.49	0.49	110	1.98	1.82
8/30/79	WASSON 3	1337	1X4	73	89	95	106	126	129	135	135	0.44	0.44	0.43	63	3.03	1.81
8/30/79	WASSON 4	1337	1X4	113	113	108	121	121	125	125	131	0.42	0.49	0.55	76	-1.03	1.96
8/30/79	WASSON 5	1337	2X2	213	173	0	0	123	125	0	0	0.40	0.00	0.00	89	1.57	0.90
9/02/79	MORONGO	61-1354	2X2	263	223	0	0	108	103	0	0	0.56	0.00	0.00	161	2.00	1.06
9/03/79	OLIVE 1	1365	2X2	63	60	0	0	121	127	0	0	0.48	0.00	0.00	51	0.54	0.98
9/03/79	OLIVE 2	1365	2X2	245	239	0	0	114	114	0	0	0.33	0.00	0.00	153	2.27	0.83
9/03/79	OLIVE 3	1365	4X1	140	0	0	0	114	0	0	0	0.00	0.00	0.00	93	-1.24	0.50
9/07/79	YNEZ	1398	1X4	114	91	70	64	0	0	0	0	0.58	0.57	0.62	64	1.80	2.27
9/11/79	HIGHLAND	938	2X2	124	106	0	0	0	0	0	0	0.51	0.00	0.00	88	1.80	1.01
9/12/79	SAN FELIPE 1	947	2X2	161	138	0	0	0	0	0	0	0.24	0.00	0.00	93	1.32	0.74
9/12/79	SAN FELIPE 2	947	2X2	183	165	0	0	0	0	0	0	0.44	0.00	0.00	100	1.84	0.94
9/13/79	CANYON 1	1456	1X4	200	188	175	165	0	0	0	0	0.20	0.18	0.18	113	2.21	1.07
9/13/79	CANYON 2	1456	1X4	99	73	51	30	0	0	0	0	0.46	0.43	0.40	15	1.50	1.80
9/13/79	CANYON 3	1456	2X2	131	86	0	0	0	0	0	0	0.48	0.00	0.00	63	0.80	0.98
9/13/79	ORTEGA	1454	2X2	176	153	0	0	0	0	0	0	0.38	0.00	0.00	89	1.56	0.88
??	SAN DIA 1	??	4X1	124	0	0	0	0	0	0	0	0.00	0.00	0.00	63	0.68	0.50
??	SAN DIA 2	??	1X4	189	150	113	88	0	0	0	0	0.42	0.36	0.44	79	1.79	1.72
??	SAN DIA 3	??	2X1	83	0	0	0	0	0	0	0	0.00	0.00	0.00	56	0.30	0.50

1/ Order Number, CDF or FS Fire Number.
2/ Columns 1-4 refer to release numbers.
3/ Delay 1 is time between first and second release, Delay 2 is time between second and third release, and Delay 3 is time between third and fourth release.
4/ Time before (-) or after (+) initial release to point of minimum drop height.

George, C. W. Measurements of airtanker drop conditions during firefighting operations. Res. Pap. INT-299. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1982. 10 p.

Operational parameters for an S2F airtanker were monitored on a series of wildland fires to verify previous assumptions concerning typical flight envelopes. Results confirmed the validity of the procedure and instrumentation used in obtaining real-time aircraft drop height, speed, drop configuration, release sequence, and other related data. In-flight measurements support general assumptions made during previous studies dealing with delivery systems, retardant properties, and in the development of guidelines derived therefrom.

KEYWORDS: airtanker, tank and gating system, firefighting mission, operational use, envelope, drop conditions, drop height, aircraft speed, drop configuration, release sequence, fire retardant, ground distribution pattern, safety

The Intermountain Station, headquartered in Ogden, Utah, is one of eight regional experiment stations charged with providing scientific knowledge to help resource managers meet human needs and protect forest and range ecosystems.

The Intermountain Station includes the States of Montana, Idaho, Utah, Nevada, and western Wyoming. About 231 million acres, or 85 percent, of the land area in the Station territory are classified as forest and rangeland. These lands include grasslands, deserts, shrublands, alpine areas, and well-stocked forests. They supply fiber for forest industries; minerals for energy and industrial development; and water for domestic and industrial consumption. They also provide recreation opportunities for millions of visitors each year.

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